ESE-04409

Thermal Management of Electronics

Annual Status Report

for

Office of Naval Technology

Arlington, Virginia

December 1990

Prepared by

Kevin G. Beasley

Naval Weapons Support Center

Code 6042, Building 2044

Crane, Indiana

Background

Electronic components are becoming more complex and at the same time becoming more densely packaged and decreasing in size. The need for a more efficient method of dissipating the heat generated by these components exists. Weight and volume limitations for systems used in avionics and shipboard electronics requires more volume efficient packaging of these components. In addition to increased volume efficiency, thermal management of these electronics must be enhanced. This may include active and passive methods of dissipating the generated heat. Passive methods include physical configuration and/or materials. A component of these electronic systems is the Standard Electronic Module(SEM). Electronic components make up these SEMs along with connecting and structural components, that have been made standard so that the modules are easily replaced if required. Guide rib conduction cooling is a method of dissipating the heat out of SEMs by using the various components as thermal paths to the cardrail, which has either water or air traveling through the cooling ducts and out of an enclosure. This effort is utilizing new material configurations to improve the thermal performance of SEMs and other similar applications.

Objective

The objective of this work is to use new materials and techniques to improve the thermal performance of electronic systems. The composite work will focus on corrosion protection of aluminum/graphite heatsinks and development of techniques to adequately machine continuous fiber composite material. Metal and polymer matrix composites will be developed for SEM heatsinks. Composite cardrails will also be developed using high thermal conductivity graphite fibers. Using the fact that composite materials can be CTE controlled, these materials will be used to constrain epoxy PWBs. This task will also look at various plating materials to attempt to decrease thermal contact resistance between the module guide rib and the enclosure cardrail. Alternate substrate materials, such as aluminum nitride, will be investigated for ceramic PWBs. The use of diamond will also be investigated to improve thermal performance.

Assessment of the benefits gained from these materials will be made to indicate the extent of improvement to the overall system.

Composite Heatsinks

A specification was developed which identifies requirements and test methods to procure composite module heatsinks. It is planned to incorporate these requirements into MIL-C-28754. This specification will be used to procure heatsinks in FY91. A Navy Manufacturing Technology (MANTECH) Program to reduce the cost of high thermal conductivity graphite fibers is going to use MIL-C-28754/92 and the above composite module heatsink specification. A deliverable of this MANTECH program is sixteen(16) SEM E composite module heatsinks. NWSC Crane is working closely with NSWC White Oak and AMOCO Performance Products, Inc. on the requirements for the SEM E composite module heatsinks. See Appendix A for this Composite Module Heatsink Specification.

Using a water cooled fixture that simulates a water cooled electronic enclosure drawer thermal conductivity of a flat plate can be measured. A procedure has been developed using heating pads, thermocouples, and the above fixture that will consistently produce a value for thermal conductivity of materials in the X and Y directions(in-plane). In measuring thermal conductivity in these directions Z-direction thermal conductivity is also a factor, but a value for strictly Z-direction is not obtainable using this procedure. These materials may be unreinforced metal and composite materials that are currently or will be used as SEM heatsinks.

Much of the work on graphite/aluminum composites has focused on the prevention of corrosion between the graphite and the aluminum. The key to this prevention seems to be to isolate the graphite/aluminum interface from the environment. One such method that has obtained good results has been to Ion Vapor Deposition(IVD) additional aluminum on the graphite/aluminum composite. This IVD process isolates the interface from the environment with a layer of aluminum. The composite that has been subjected to the IVD process can then be treated to protect the aluminum base material from the environment. Such treatments that have proved successful are anodizing, chromate coating, a ceramic coating, and a teflon coating. The effectiveness of these finishes can be evaluated by subjecting samples to the MIL-STD-810 48-hour salt fog test.

NWSC Crane has had extensive contacts with composite heatsink users that are also attempting to develop composite heatsinks for their own applications. These companies have been involved in Internal Research and Development(IRAD) and Small Business Innovation Research(SBIR) programs in development of composites for these purposes. NWSC Crane has taken part in evaluation of proposals and progress reviews of these programs. This allows NWSC Crane to participate in these programs and to influence work direction when requested. NWSC Crane has also had extensive contacts with composite manufacturers. NWSC Crane has informed these manufacturers of the Navy requirements and worked with them to produce composite materials that would meet SEM heatsink requirements. Metal matrix composite material has been received from DWA Composite Specialties, Inc. and Fiber Materials, Inc.. Organic matrix composite material has been received from Martin Marietta, Baltimore, MD.

Composite material that NWSC Crane has received has undergone some evaluation in accordance with SEM heatsink requirements. Metal matrix composite material with various protective finishes have been subjected to salt fog tests and thermal conductivity measurements. All material that has been IVD aluminum has gone through the salt fog test without base material corrosion. Metal matrix composites have also been measured for flatness and surface roughness. Some material remains unsatisfactory with respect to flatness and surface roughness. In addition, some machinability evaluation has been done using conventional tooling on material from Fiber Material, Inc. and appears to be acceptable. Thermal conductivity measurements have also been made on the organic matrix composite material and the value was 405 W/m°C in the x-direction, but coefficient of thermal expansion of this material was negative.

Work at the Naval Postgraduate School investigated corrosion characteristics of graphite/aluminum composite. The composite was found to be susceptible to several different forms of corrosion attack in 3.5% NaCl aqueous solution. The most vigorous attack occurred at exposed graphite/aluminum interfaces. The pH factor of the solution was varied from 4 to 8. The composite was more susceptible to corrosion when immersed in a solution of pH 4 than in pH 8. This work confirms other data that indicated if the edges of the composite are protected from the environment accelerated corrosion will not occur until localized corrosion perforates the composite's surface foil.

NWSC Crane expects to award two contracts concerning composite SEM heatsinks. One contract is to investigate methods to improve the Z-direction thermal conductivity, especially at the guide ribs. The other contract will address issues concerning organic matrix composite heatsinks. Solicitations have been issued for this work. It is anticipated that these contracts will be awarded in April, 1991.

NWSC Crane monitored two Small Business Innovation Research(SBIR) programs. These SBIRs focused on composite materials for use as heatsinks. Topic no. N89-095, Integral Dielectric/Heatsink for Electronic Devices, had four contractors and topic no. N89-097, Polymer Matrix Composite Heatsinks for Electronic Devices, had three contractors. Both were to be completed in December, 1990. It is anticipated that one contractor from each topic will be selected to participate in a Phase II SBIR.

Composites for Enclosures

The Naval Avionics Center(NAC), Indianapolis, IN was funded by NWSC Crane to investigate the use of composite materials for electronic enclosures. Their tasks focused on using composite materials in the fabrication of a 3/4 Air Transport Rack(ATR) enclosure shell and to investigate Electro-Magnetic Interference(EMI) protection for organic matrix composite enclosures.

NAC fabricated in-house two 3/4 ATR enclosure shells. One being graphite reinforced epoxy and the other fiberglass reinforced epoxy enclosure shell. NAC also contracted with ICI Fiberite, Inc. to fabricate a graphite reinforced epoxy 3/4 ATR using flat panel construction. ICI Fiberite, Inc. did deliver a enclosure to NAC. Evaluation of this enclosure will take place next year. EMI protection and structural characteristics will be evaluated. Kevlar pre-impregnated reinforced materials for enclosure development and circuit board substrate manufacturing was procured. This material will be used to fabricate a 3/4 ATR enclosure shell at NAC.

NAC efforts also included looking at various coatings and processes of plating polymer matrix composites for EMI protection. The different materials that were looked at were copper nickel, nickel alloys, aluminum, silver, and zinc. The different processes used to apply there materials were electroless plating, flame spraying, plasma spraying, sputtering, and Ion Vapor Deposition(IVD). The actual testing of the material will be done in the coming months. The testing will determine the effectiveness of the various coatings and processes.

Multi-component incorporation

NWSC Crane has developed a Module Thermal Analysis Computer Program and a Component Thermal Analysis Computer Program that can be used on an IBM pc or compatible. The Module Thermal Analysis Program is used to predict temperatures at the circuit board surface given certain power load and guide rib temperatures. The Component Thermal Analysis Program is used to predict component junction temperatures given power load and the temperature of the base of the package. Both programs have the capability of varying the materials used in the package, circuit board, and heatsink. These programs will be used to determine potential benefits from the use of advance materials, such as Aluminum Nitride(AlN) substrates for circuit boards, diamond films, and composite heatsinks.

NWSC Crane and NAC are working together on depositing diamond films onto ceramic surfaces. These surfaces being either the circuit board surface or inside the ceramic package between the package and the chip. NAC has attempted to deposit diamond onto 96% alumina(Al_2O_3) substrates provided by NWSC Crane. The results thus far has been that the standard 96% alumina is not dense enough and the surface is too rough when used with NAC's procedure. The surfaces were then polished and diamond was again deposited onto the surface. The results indicated that the standard 96% alumina was not dense enough. This shows that there is likely to be some optimum density and surface roughness that will produce a good diamond film on the ceramic surface. Denser alumina will now be used to deposit the diamond film onto.

Printed Wiring Board(PWB) Constraining

NWSC Crane has performed some modeling of PWB constraining boards. This modeling has been done using Material Sciences Corporation(MSC) "class" computer program. This computer program can be used on a IBM pc or compatible. NWSC Crane is developing the capability to measure the surface thermal expansion using strain gages. NWSC Crane has also worked with Research Opportunities, Inc.(ROI) in performing thermal cycling of PWB material. Much of this PWB material contained composite constraining layers.

NWSC Crane plans to obtain graphite composite material and to fabricate PWBs with it. Evaluation of this material will be performed at NWSC Crane and other facilities.

Thermal Contact Resistance

A contract was awarded to Texas A&M, College Station, Texas to investigate the decrease of thermal contact resistance between a SEM heatsink guide rib and an enclosure cardrail. Phase I of this contract will investigate various platings and/or techniques that may be done to the heatsink guide rib to decrease this thermal resistance at the guide rib/cardrail interface. NWSC Crane will have the option to exercise Phase II and III of this contract, Which focuses on the aluminum cardrail and specifically metal matrix composite heatsinks respectively. This is a 12 month contract, therefore Phase I work should be complete by the end of 1991.